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Optimization of Surface Roughness (SR) in Wire Electric Discharge Machining

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ABSTRACT- *Present study has been made to optimize of surface roughness in EN 24T steel. Three input parameters pulse on time, pulses off time, servo voltage were chosen as variable to study the process parameter. The analysis of variance (ANOVA) was carried out for study the effect of process parameters on process performance. In addition mathematical models have also been developed for response parameter. Properties of the machined surface have been examined by surface roughness tester. For the different values of the three input parameters developed L27 orthogonal array by taguchi method. Here the surface roughness is measured with the help of surface roughness tester SJ-210. This tester is diamond tip which measure accurate value of surface roughness.*

Keyword: *- WEDM, Pulse on time, Pulse off time, Servo Voltage, SR.*

1. INTRODUCTION

In Wire Electrical Discharge Machining (WEDM), or Wire-Cut EDM, a thin single-strand metal wire is fed through the work piece, typically occurring while in a submerged tank of dielectric fluid or deionized water. This fluid to cool the process and flush away the cut material. The Wire EDM process uses electric current to cut conductive materials leaving a smooth surface that requires no further finishing or polishing. This process is used to cut plates and to make punches, tools, and dies from any conductive material, including hard metals that are too difficult to machine with other methods, such as; metal allows, graphite, carbide and diamond. The wire is held between upper and lower diamond guides. The guides move in the (X-Y) plane controlled by a CNC, the upper guide can also move independently in the (Z-U-V) axis, giving rise to the ability to cut tapered and transitioning shapes and can control axes movements. This gives the Wire-Cut EDM the ability to be programmed to cut very intricate and delicate shapes. Wire EDM is commonly used when low residual stresses are desired. Wire EDM has no added residual stress because it has no cutting forces. There is little change in the mechanical properties of a material in Wire EDM due to its low residual stresses. The cutting wire never touches the material, the cutting itself is due to the erosion that occurs when a spark forms between the cutting wire and raw material. A typical Wire EDM process with consist of several passes, moving at various speeds. The first passes are typically fast moving, lower accuracy to remove large amounts of material. Later, skim passes, will retrace the cuts at lower speeds, removing less material but improving the surface quality and accuracy of the cut. If complex cut outs are required, a pre-drilled hole through a raw material can be threaded with a Wire EDM and the machine can begin cutting from there. Applications for Wire EDM include the creation of extrusion dies, blanking punches and metal and tool fabrication.

2. WORKING PRINCIPLE OF WEDM

Wire-cut EDM is typically used to cut plates as thick as 300mm and to make punches, tools, and dies from hard metals that are difficult to machine with other methods. Wire-cutting EDM is commonly used when low residual stresses are desired, because it does not require high cutting forces for removal of material. If the energy/power per pulse is relatively low (as in finishing operations), little change in the mechanical properties of a material is expected due to these low residual stresses, although material that hasn't been stress-relieved can distort in the machining process. Due to the inherent properties of the process, wire EDM can easily machine complex parts and precision components out of hard conductive materials. Wire EDM is an electro-thermal non-traditional machining process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. Use electric current and fine wire to cut conductive materials. The cutting typically occurs while the work piece is submerged in deionized water. Deionized water helps to cool the process and flush away the cut material. Cutting wire does not touch the material. Cutting itself is due to the erosion that occurs when a spark forms between the cutting wire and the raw material.

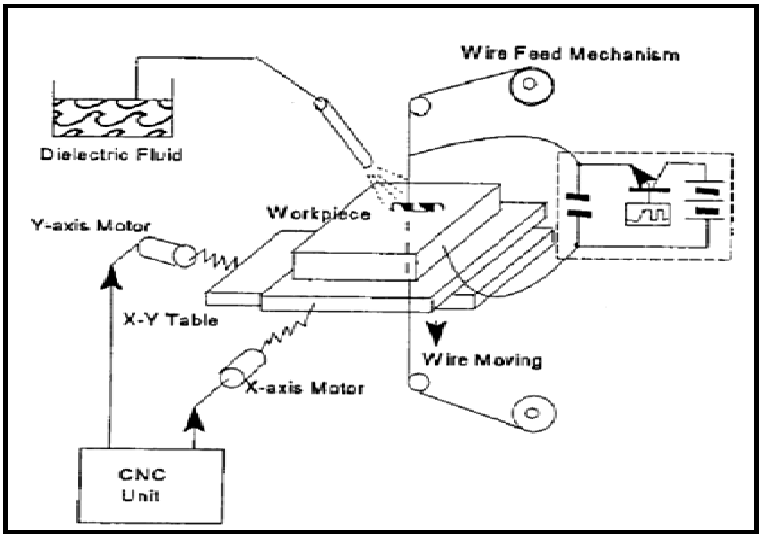

Fig 2.1 Diagram of working of WEDM

3. LITERATURE REVIEW

They use Taguchi technique and response surface methodology in machining of AISI D2 Steel. The objective of the present work is to investigate the effects of various WEDM process parameters such as pulse on time, pulse off time, servo voltage and wire feed rate on the Material Removal Rate, Surface Roughness (SR) and cutting rate. Secondly, to obtain the optimal settings of machining parameters at which the MRR and cutting rate are maximum and the Surface Roughness is minimum in a range. The experiments were carried out as per design of experiment approach using L27 orthogonal array. AISI D2 steel specimen is machined by using brass wire as electrode and the response surface methodology (RSM) is used for modelling a second-order response surface to estimate the optimum machining condition to produce the best possible response within the experimental constraints. The results from this study will be useful for manufacturing engineers to select appropriate set of process parameters to machine AISI D2 steel **[1].**

This study on the development of model and its application to estimation of machining performances using Multiple Regression Analysis (MRA), Group Method Data Handling Technique (GMDH) and Artificial Neural Network (ANN). Experimentation was performed as per Taguchi's L'16 orthogonal array. Each experiment has been performed under different cutting conditions of pulse-on, pulse-off, current and bed speed. Among different process parameters voltage and flush rate were kept constant. Molybdenum wire having diameter of 0.18 mm was used as an electrode. Three responses namely accuracy, surface roughness, volumetric material removal rate have been considered for each experiment **[2].**

They study the surface properties of EN-31 die-steel after machining with powder metallurgy EDM electrodes. A lot of experimentation has been carried out to find the optimum parameters for the EDM process. Researchers have also used powder metallurgy electrodes to study their influence on surface properties and output process parameters. In this paper, powder metallurgy electrodes prepared with different compositions of copper and manganese has been used to machine EN-31 die-steel. Comparisons have been made with copper electrode for micro hardness and surface roughness behaviour of work piece and it has been found that copper-manganese (in weight ratio 70-30) composite electrode shows better results than copper-manganese (in weight ratio 80-20) electrode and copper electrode **[3].**

In which they do experimental investigation and optimisation of performance characteristics in EDM of EN-24 alloy steel using Taguchi Method and Grey Relational Analysis. This investigation addresses exploration of EDM process on EN-24 alloy steel using Taguchi robust design approach and multi Objective Grey Relational Grade with four controllable input parameters such as Pulse on time, Pulse off time, Peak current and Flushing pressure for analysis of MRR and Tool wear rate. The design matrixes for experimentation with different treatment conditions are chosen utilising L9 orthogonal array. From detailed study, it is found that different combinations of EDM process parameters are necessary to achieve enhanced MRR and reduced TWR for EN-24 alloy steel. In this study, single objective optimization is established by Taguchi methodology and optimal factor settings for multi objective optimization of two output responses MRR and TWR collectively are identified using Grey relational analysis. Significant contribution of input controllable parameters on output response MRR is also identified statistically **[4].**

They optimise and prediction of material removing rate in die sinking electro discharge machining of EN45 steel tool. The main aim of this paper is to maximization of MRR in die sinking electro-discharge machining of EN45 material using Taguchi method. EN45 is a manganese spring steel with high carbon content. EN45 is used widely in the motor vehicle industry for leaf springs, truncated conical springs, helical springs and spring plates and many general engineering applications. The experiments conducted based on the L27 Orthogonal array and results were optimized. Experiment were carried out using four input parameters viz. peak current, pulse on time (Ton), pulse off time and voltage with three different levels. The effects of different input parameters and effect of their combination on MRR determined using Taguchi and ANOVA table. It was observed that peak current and pulse off time are more significant factor for MRR **[5].**

Study about effect and optimization of machine process parameters on MRR for EN19 & EN41 materials using taguchi method. The present work deals with the comparison of the MRR for EN19 and EN41 material in a die sinking EDM machine. The various input factors like Pulse ON time, Pulse OFF time, Discharge current and voltage were considered as the input processing parameters, while the MRR is considered as the output. Optimization using Taguchi method was performed to predict the best combination of inputs towards maximum output. A comparison was done to obtain the effect of these input parameters over the MRR for both the material, and simultaneously the impact of the carbon percentage over the MRR was investigated. It was found that the Discharge current in case of the EN41 material and EN19 material had a larger impact as compare to other processing parameters on the MRR. A relative study of the carbon composition for both the material was also done **[6].**

In which study of Taguchi method in of preference by similarity to ideal solution (TOPSIS) and Grey Relational Analysis (GRA) have been adopted to evaluate the effectiveness of optimizing multiple performance characteristics for PMEDM of H-11 die steel using copper electrode. The effect of process variables such as powder concentration, peak current, pulse on time (Ton), duty cycle (DC) and gap voltage (Vg) on response parameters such as Material Removal Rate (MRR), Tool Wear Rate (TWR), Electrode Wear Ratio (EWR) and Surface Roughness (SR) have been investigated using chromium powder mixed to the dielectric fluid. Analysis of variance (ANOVA) and F-test were performed to determine the significant parameters at a 95% confidence interval. Predicted results have been verified by confirmatory tests which show an improvement of 0.161689 and 0.2593 in the preference values using TOPSIS and GRA respectively **[7].**

Electro-Discharge Machining (EDM) is one of the non-conventional machining processes available, in which the material removal takes place due to melting and vaporisation of electrode materials. Micro Electro-Discharge Machining (μ-EDM) is a variant of EDM, is playing an important role in generation of micro features on difficult to machine conducting materials. In this Paper, authors carried out an extensive literature study to give a complete description on μ-EDM process, its requirements, performance and applications. More than fifty papers were referred and the details were categorized into five major areas, namely, experimental setups and its subsystems, experimental studies and optimization methods, generated micro features, modelling and simulation approaches and applications **[8].**

Wire Electrical Discharge Machining (WEDM) is a specialized thermal machining process capable of accurately machining parts with varying hardness or complex shapes, which have sharp edges that are very difficult to be machined by the main stream machining processes. This study outlines the development of model and its application to estimation of machining performances using Multiple Regression Analysis (MRA), Group Method Data Handling Technique (GMDH) and Artificial Neural Network (ANN). Experimentation was performed as per Taguchi's L'16 orthogonal array. Each experiment has been performed under different cutting conditions of pulse-on, pulse-off, current and bed speed. Among different process parameters voltage and flush rate were kept constant **[9].**

In this research, input parameters such as pulse on time (TON), pulse off time (TOFF), peak current (IP), wire feed (WF), wire tension (WT), and servo voltage (SV) has been selected for process capability investigation in WEDM process. The process capability index was evaluated for machining characteristics such as machined work-piece dimension (MWD) and surface roughness (SR). Taguchi's approach to experiment design and analysis was utilized to study the influence of machining parameters on the process capability index. Single response optimization was performed for both machining characteristics to find out the parametric setting which could optimize WEDM process capability. Surface integrity aspects such as microstructure analysis of the selected machined titanium samples have also been investigated **[10].**

4. OBJECTIVES

- To Study the effect of input variable parameters on performance parameters.
- To get the optimum input & output parameter for selected wire & work piece material.
- To study about the SR in WEDM & its optimization.
- To find out the problems of wire breaking during machining.

5. EXPERIMENTAL SETUP

- **Specification of machine:**

Table 1. Machine specification

SPECIFICATION	DESCRIPTION
Main axes travel	500*300 mm
Max. work piece height	260 mm
Max. work piece weight	500 kg
Aux. axes traverse	100*100 mm
Max. taper angle	35°
Max. cutting speed	250 mm/min
Work table size	810*550 mm
Best surface finish	0.25 µ Ra
Max. wire spool capacity	8 kg
Controlled axes	X,Y,u,v,Z
Di-electric fluid	Di-ionized water

- **Work piece material:** EN–24 tool steel

EN 24 has the wide applications in stamping dies, metal cutting tools or any other industries because of its high strength and heavy weight. In general the edge temperature under expected use is an important determine of both composition and required heat treatment.

Table 2. Chemical composition of work piece material

Chemical composition of EN 24T steel							
C	SI	MN	S	P	Cr	Mo	Ni
0.36/0.44	0.10/0.35	0.45/0.70	0.040 max	0.035 max	1.00/1.40	0.20/0.35	1.30/1.70

- **Wire material:** Hard Brass Zinc Coated Wire

Zinc coated brass wire was one of the first attempts to present more zinc to the wire's cutting surface. This wire consists of a thin (approximately 5 micron) zinc coating over a core which is one of the standard EDM brass alloys. This wire offers significant increase in cutting speed over plain brass wires, without any sacrifice in any of the other critical properties.

Fig 5.1 Wire electrical discharge machine

Table 3. Factors and Levels

Symbol	Input Parameters	Level 1	Level 2	Level 3
A	Pulse On Time (μs)	**110**	**120**	**130**
B	Pulse Off Time (μs)	**40**	**50**	**60**
C	Voltage (volt)	**110**	**120**	**130**

Output parameter: Surface roughness

Surface roughness is important parameter in wire EDM process. In this experiment by applying different values of pulse on time, pulse off time, and servo voltage, different values for SR is as table 4. Surface roughness is measure by SR tester.

Fig 5.2 SR tester

Table 4. Specification of SR tester

Sr. No.	Specifications	Units
1	Method	Differential inductance
2	Stylus	Diamond TIP
3	TIP radius	5 μm (200 μ inch)
4	Make	Mitutoyo
5	Model	SJ-210
6	Measuring range	-200 μm to + 150μm
7	Measuring Force	4mN(0.4gf)
8	Sampling length	2.5 mm x 5

6. RESULTS AND ANALYSIS

Table 5. Results

SR.NO	Pulse on time(μs)	Pulse off time (μs)	Servo Voltage (volts)	SR (micrometer)
1	110	40	110	4.29
2	110	40	110	4.28
3	110	40	110	4.27
4	110	50	120	4.19
5	110	50	120	4.18
6	110	50	120	4.17

7	110	60	130	4.36
8	110	60	130	4.38
9	110	60	130	4.39
10	120	40	110	5.50
11	120	40	110	5.51
12	120	40	110	5.52
13	120	50	120	5.20
14	120	50	120	5.19
15	120	50	120	5.21
16	120	60	130	5.25
17	120	60	130	5.28
18	120	60	130	5.35
19	130	40	110	5.90
20	130	40	110	6.10
21	130	40	110	6.08
22	130	50	120	6.10
23	130	50	120	6.18
24	130	50	120	6.15
25	130	60	130	6.60
26	130	60	130	6.65
27	130	60	130	6.70

A collection of data is accomplished after cutting the EN 24T steel material by wire EDM. Machining time has been observed and noted after each experiment and surface roughness is measured with the help of surface roughness tester SJ 210. For different 27 set of input parameters there are accurate value for surface roughness get with SR tester. Here the result for surface roughness given in above table 4.

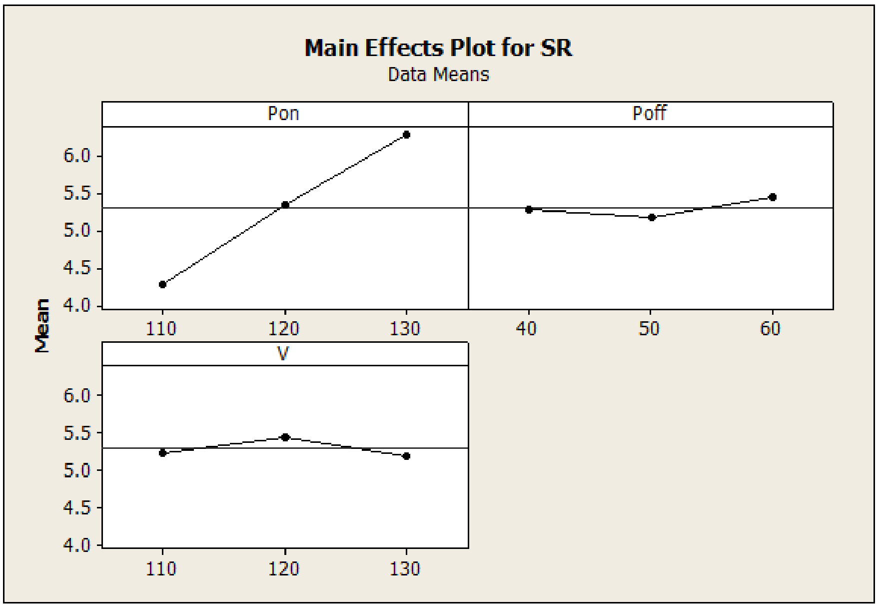

Fig 6.1 Main effect plot for SR

Main effect plot for SR is as shown above fig 6.1. In which for different input parameters and there different range set of input values gives main effect plot for three input parameter. For pulse on time as the value increase the value for SR has also increase. For pulse off time in first input value SR is higher but as the value increase for second stage the value of SR is decrease. But at the last input value SR has increase. Now for servo voltage for initial stage SR increase and further decrease.

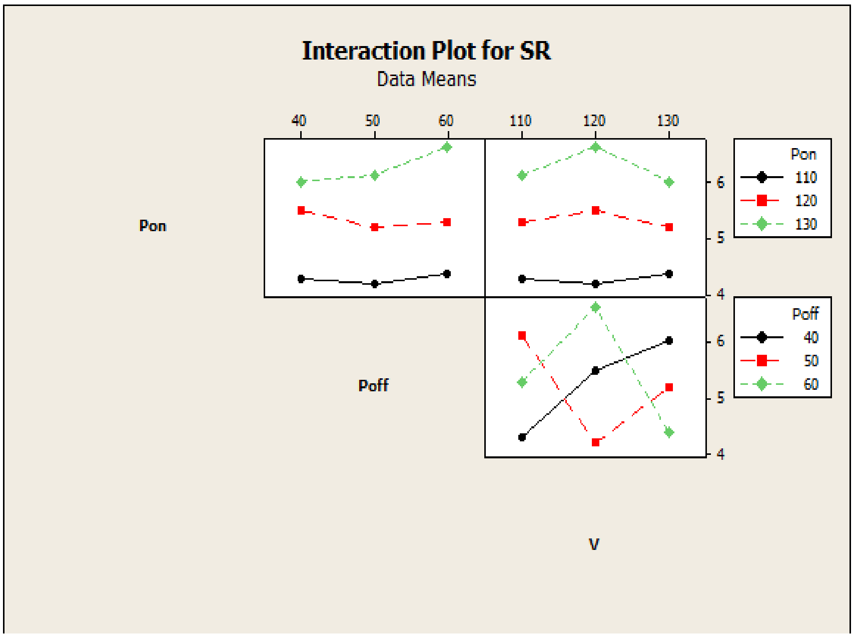

Fig 6.2 Interaction plot for SR

Interaction plot for SR is as shown in above fig 6.2 for three input parameters. Here three stages for input parameter of wire EDM. There is different graph has been generated by using matlab 16. All results of surface roughness is generated by use of interaction plot.

- **Optimization Using Genetic Algorithm:**

Table 6. Results of optimization using GA

Ext No.	Process variables			Response
	V	Pon	Poff	SR
Population size : 50				
1	120	110	50	4.18

- **Confirmatory Experiment:**

Table 7. Valedictory experiment

Input parameters	Value	Optimized value of SR	Experimental value of SR	% Error
Voltage	120	4.18	4.17	-0.23%
Pulse on time	110			
Pulse off time	50			

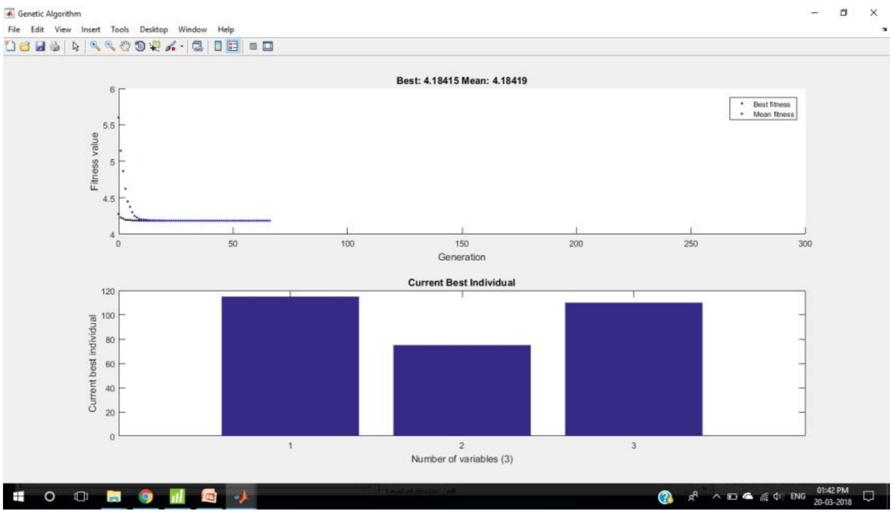

Fig 6.3 Optimization Using Genetic Algorithm

7. CONCLUSIONS

- **Effect of process parameters on SR was concluded as under :**

In this experiment as the value of voltage increase, value for surface roughness increase as per the range of given voltage. For pulse on time, when value increase than value of SR also increase. For pulse off time for some range SR is increase and further decrease as the pulse off time increase. For the different set of this three input parameter we get different values for the surface roughness. By the use of surface roughness tester SJ 210 we can get the highly accurate result for SR.

- **Conclusions from GA optimization:**

The Genetic Algorithm was used for optimization. Following was concluded for the different set of input parameters those results in surface roughness. The regression models were subjected to optimization process and have given near about optimal values for input parameters. Genetic Algorithm was able to reach the optimal solution, after satisfying the constraints. This was validated in present work practically, after performing a confirmatory experiment as per process parameters optimized by GA for different input parameters. Maximum error of 4% was found between the optimized value the experimental value for output parameters of WEDM.

8. REFERENCES

[1] Vikram Singh, S.K. Pradhan.”Optimization of WEDM parameters using taguchi technique and response surface methodology in machining of AISI D2 steel.” Procedia Engineering 97 (2014): 1597 – 1608.

[2]G.Ugrasen, H.V.Ravindra, G.V.Naveen Prakash, R.Keshavamurthy. ”Estimation of machining performances using MRA, GMDH and artificial neural network in Wire EDM of EN-31.” Procedia Materials Science 6 (2014)1788 – 1797.

[3]Parveen Goyal, N M Suri, Sanjeev Kumar, Rajesh Kumar.”Investigating the surface properties of EN-31 die-steel after machining with powder metallurgy EDM electrodes.” Materials Today: Proceedings 4 (2017) 3694–3700.

[4] B.P. Mishra, B.C. Routara.” An experimental investigation and optimisation of performance characteristics in edm of en-24 alloy steel using taguchi method and grey relational analysis.” Materials Today: Proceedings 4 (2017) 7438–7447.

[5] Sumit Raj, Kaushik Kumar.” Optimization and prediction of material removing rate in die sinking electro discharge machining of en45 steel tool.” Materials Today: Proceedings 2 (2015) 2346 – 2352.

[6] Vikas, Shashikant, A.K.Royb and Kaushik Kumar.” Effect and optimization of machine process parameters on mrr for en19 & en41 materials using taguchi.” Procedia Technology 14 (2014) 204 – 210.

[7] S. Tripathy, D.K. Tripathy.” Multi-attribute optimization of machining process parameters in powder mixed electro-discharge machining using TOPSIS and grey relational analysis.” Engineering Science and Technology, an International Journal 19 (2016) 62–70.

[8] Leera Raju, Somashekhar S Hiremath.” A state of the art review on micro electro-discharge machining.” Procedia Technology 25 (2016) 1281 – 1288.

[9] G.Ugrasen, H.V.Ravindra, G.V.Naveen Prakash, R.Keshavamurthy.”Estimation of machining performances using MRA, GMDH and artificial neural network in wire EDM of EN-31.” Procedia Materials Science 6 (2014) 1788 – 1797.

[10] Rupesh Chalisgaonkar, Jatinder Kumar.” Process capability analysis and optimization in WEDM of commercially pure titanium.” Procedia Engineering 97 (2014) 758 – 766.